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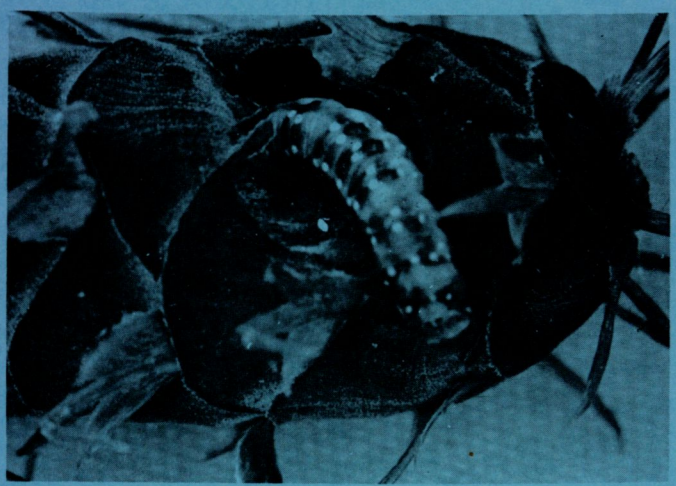

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A STUDY OF INSECTS ATTACKING DOUGLAS-FIR CONES IN EASTERN MONTANA AND YELLOWSTONE NATIONAL PARK

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By
Jerald E. Dewey and Frederick W. Honing, Entomologists
Forest Insect and Disease Branch

ABSTRACT

Evaluations of nine permanent plots in Montana east of the Continental Divide show a high percentage of Douglas-fir cones and seed was destroyed by spruce budworm, Choristoneura fumiferana (Clemens). Of lesser importance were the fir coneworm, Dioryctria abietivorella (Grote); a Douglas-fir cone moth, Barbara colfaxiana (Kearf.); Douglas-fir scale midge, Contarinia washingtonensis Johnson; and the Douglas-fir seed chalcid, Megastigmus spermatrophus Wachtl.

INTRODUCTION

Insects that destroy the seeds of forest trees have an important bearing on reforestation. When a high percentage of a seed crop is destroyed in any year, seed collecting may be unprofitable and nursery establishment and planting will be greatly hampered. A loss of seed may also seriously threaten the natural reestablishment of commercially valuable tree species, particularly on burned or cutover lands where timing of seeding may be highly critical (Keen 1958).

Douglas-fir is one of our most valuable timber tree species. Presently there are about 9 million acres of forest land classified as Douglas-fir type in the Northern Region. In 1962, almost a billion board feet of Douglas-fir were harvested (Wilson and Spencer 1967). Much of this cutover land, as well as fire-destroyed forest land, has failed to restock satisfactorily.

Factors limiting the supply and viability of seed are, in a large part, responsible for unsatisfactory restocking. Some limiting factors are:

1. The cone crop of Douglas-fir fluctuates greatly. The subsequent seed crop may vary from heavy to almost complete failure. Good crops are borne about every 3 to 7 years with light crops in between.

2. Several species of rodents and birds feed on large amounts of Douglas-fir seed. A 2-year study in Oregon showed that 88 percent of the Douglas-fir seed that reached the ground was destroyed by birds, small mammals, and other agents before germination. Birds and small mammals alone were responsible for 63 percent of this seed loss (Gashwiler 1967).

3. Much of the seed is hollow and infertile. The reason for this is not known. In this study, of the 2,700 seeds dissected, 45 percent were hollow.

4. Insects frequently are extremely injurious and are a major factor in reducing the supply of seed. Studies on seed-destroying insects can undoubtedly do much to alleviate regeneration problems.

Studies and evaluations of insects that attack and destroy Douglas-fir cones and seed are incomplete in the Northern Region. Because foresters need this information to assist them in better management of timber stands, a study was initiated in selected stands of Douglas-fir in eastern Montana and Yellowstone National Park during 1967.

The objectives of this study were to:

1. Determine species and numbers of Douglas-fir cone and seed insects present in the study area.

2. Determine the amount of injury caused by each insect species.

METHODS AND PROCEDURES

COLLECTING AREA AND SAMPLING

Nine permanent cone collection plots were established throughout the study area. This included two each on the Helena and Gallatin National Forests, one each on the Deerlodge, Beaverhead, Custer, and Lewis and Clark National Forests, and one in Yellowstone National Park (fig. 1). Each plot was separated into three subplots, each consisting of at least three individual trees. Subplots were within 5 miles of plot center. At least 9 trees were sampled in each of nine plots, totaling 81 or more trees sampled for the entire study area at each sampling period.

Elevations ranged from 4,200 to 7,100 feet with a mean of 6,200 feet. Plot grade ranged from flat to 40 percent slope. Sample trees ranged from saplings to overmature and were in areas of a few scattered trees to very dense stands.

A sample consisted of 150 cones per subplot or 450 cones per plot. Of the 150 cones per subplot, 50 cones were from top crown, 50 from midcrown, and 50 from lower crown. Cones were collected with a 24-foot telescopic pole pruner. Samples above 24 feet were obtained by climbing the tree.

Samples were collected at 3-week intervals beginning May 15 and continuing through September 25. On the first collection, cones were not always distinguishable because many were still in the flower stage. The last collection was made after the cones had opened and much of the seed had fallen.

Most insect species reached their highest population levels at about the same time in all plots. The percent infestation was calculated from only those samples collected when insect populations were at their highest level.

The cone crop size was moderate to heavy in all areas sampled.

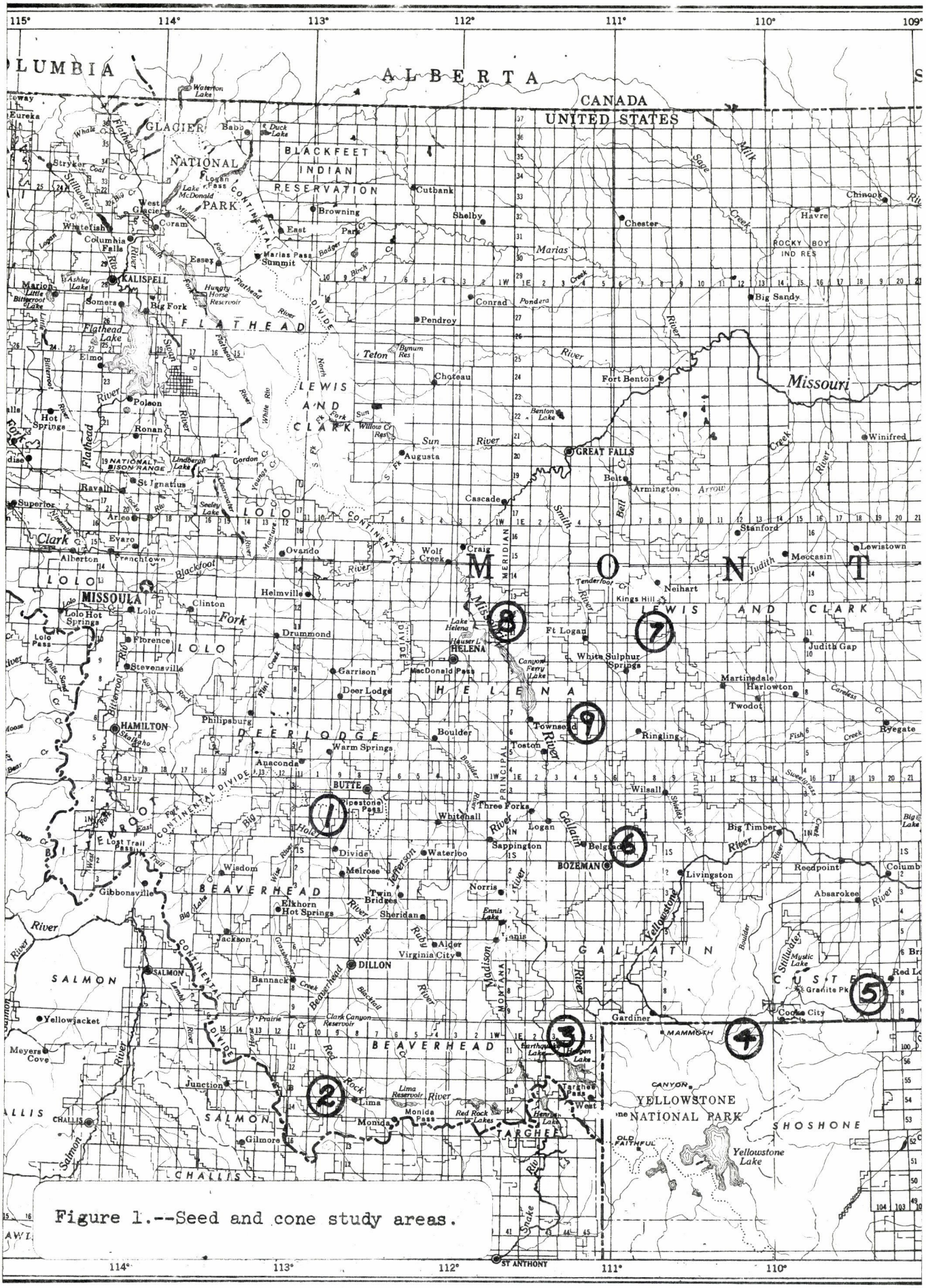

Figure 1.--Seed and cone study areas.

ANALYSIS OF CONES

Kozak (1963) made a detailed study on cone and seed insect populations in regard to crown level, outside or inside halves of live crown, directional location on crown, etc. He found minor differences between insect populations at different crown levels except for Contarinia oregonensis Foote, which showed a definite increase by crown level from bottom to top. Although cones in our study were collected from different crown levels, they were not evaluated separately other than by plots.

After each collecting trip, the cones were taken to the laboratory and 50 percent from each area were dissected. The remaining 50 percent were placed in 2-quart glass jars with screened tops to rear adults for identification. Population counts were made from the immature stages found in the dissected cones.

External symptoms such as resin exudations, chewing, frass, and abnormal growth are generally found on cones infested with insects; however, some infested cones showed no visible indication of being attacked.

RESULTS

DESCRIPTION OF CONE

Douglas-fir is a monoecious tree. Both the pollen and seed cones are borne singly on branchlets formed the previous year. The cones are bristly, scaly, conical bodies, which develop into mature cones at the end of the first season.

The mature cone is from 2 to 4 inches long, with about 50 scales per cone. Each cone has a theoretical potential of producing about 100 seeds, or 2 seeds per scale. This potential is seldom reached as many of the ovules never develop.

The cones mature in autumn when the scales open and the seeds fall. Many of the cones remain on the tree for more than a year before eventually falling, but the seeds are shed the first fall.

INSECTS PRESENT

Koerber (1960) lists 22 insect species which in some way damage Douglas-fir cones or seeds, and another 12 species reared from Douglas-fir cones whose role is unknown. He also lists 50 species of parasites and predators.

Insects that have generally been blamed for the bulk of the damage inflicted to Douglas-fir cones and seeds are:

1. Douglas-fir cone midge, Contarinia oregonensis, Foote.
2. Douglas-fir scale midge, C. washingtonensis Johnson.
3. Douglas-fir cone moth, Barbara colfaxiana (Kearf.).

4. Fir coneworm, Dioryctria abietivorella (Grote).

5. Douglas-fir seed chalcid, Megastigmus spermatrophus Wachtl.

The realtive importance of each insect species varies considerably from place to place and from year to year. The only insect listed above considered by itself to be of major importance in this study was C. washingtonensis.

The spruce budworm, Choristoneura fumiferana (Clemens), was the most injurious insect pest in this study. C. washingtonensis was found in larger numbers but caused less damage than the budworm. A number of other lepidopterous larvae were present in small numbers of little importance when considered individually, but of significant importance when considered as a group.

The dipterous maggot, Earomyia barbara McAlpine, occurred quite frequently while the Douglas-fir seed chaldid, M. spermatrophus, was rare. Aphids, Chermes cooleyi (Gillette), and thrips, Oxythrips sp. and Frankliniella sp. were found from almost every plot sampled. Two small beetles, Lathridius minutus (Linnaeus), and Corticaria sp. were collected from two plots.

Twenty-seven species of insects were reared from Douglas-fir cones and seeds; 12 were feeding on cone tissue, 12 were parasites, and the role of 3 is unknown (table 1).

ANALYSIS OF INJURY

Each insect species was evaluated separately to determine the percent of cones infested from plot to plot (table 2). The approximate date that each species reached its maximum population level was also determined.

SPRUCE BUDWORM: This pest has long been recognized as one of the most serious defoliators of several coniferous species. It is found throughout North America wherever hosts are available. In the western United States these include Douglas-fir, grand fir, subalpine fir, Engelmann spruce, and occasionally western larch. Each year millions of acres are partially defoliated in the Northern Region. Budworm defoliation has been related to considerable tree mortality in some areas.

Although volumes have been written on spruce budworm, it has never been reported as an important Douglas-fir cone and seed pest. In this study, the spruce budworm was the most destructive insect found feeding on the cones.

Budworm larvae were found in the collections the first week in June and continually increased in numbers until mid-July when 35.6 percent of all cones collected were infested with budworm. This ranged from a low of 9.3 percent to a high of 71.1 percent budworm infestation, depending on plot location.

Table 1.--Classification of insects reared from Douglas-fir cones[1/]

Cone feeders	Parasites	Miscellaneous cone associated insects
LEPIDOPTERA:	HYMENOPTERA:	DIPTERA:
Tortricidae:	Pteromalidae:	Cecidomyiidae:
Choristoneura fumiferana	*Zacalochlora milleri* Crawford	*Asynapta keeni* (Foote)
Gelechiidae:	Eulophidae:	COLEOPTERA:
Chionodes sp.	*Tetrastichus strobilus* Burks	Lathridiidae:
Filatima sp.	Braconidae:	*Lathridius minutus*
Olethreutidae:	*Apanteles fumiferana* Viereck	*Corticaria* sp.
Griselda radicana (Walsingham)	*Bracon* sp.	
Barbara colfaxiana	Ichneumonidae:	
Pyralidae:	*Campoplex* sp.	
Dioryctria abietivorella	*Exeristes comstockii* (Cresson)	
DIPTERA:	*Phaeogenes* sp.	
Cecidomyiidae:	*Glypta fumiferana* (Viereck)	
Contarinia washingtonensis	*Ichneumon* sp.	
Lonchaeidae:	Torymidae:	
Earomyia barbara	*Torymus* sp.	
HYMENOPTERA:	Eurytomidae:	
Torymidae:	*Eurytoma* sp.	
Megastigmus spermotrophus	DIPTERA:	
HOMOPTERA:	Tachinidae:	
Aphidae:	*Actia* sp.	
Chermes cooleyi		
THYSANOPTERA:		
Thripidae:		
Oxythrips sp.		
Frankliniella sp.		

1/ Insects were sent to the National Museum for identification. The Cecidomyiidae larvae were sent to Dr. N. E. Johnson, Department of Entomology, Cornell University. The Pyralidae adults were sent to Dr. W. H. Lange, Department of Entomology, University of California. The Lonchaeidae adults were identified by Dr. J. F. McAlpine, Entomology Division, Ottawa, Ontario, Canada.

Table 2.--Percent of cones infested by plots

Plot no.	Midges	Budworm	Other lepidoptera	Fir seed maggot
	- - - - - - - - - - - - Percent - - - - - - - - - - - -			
1	20.0	11.1	0.9	0.4
2	29.8	29.3	2.7	5.3
3	46.7	41.3	.4	8.4
4	16.0	41.8	5.8	1.8
5	84.0	20.4	.4	5.8
6	17.3	71.1	4.0	.4
7	51.6	9.3	.9	4.9
8	68.4	44.0	23.0	3.1
9	13.8	52.0	1.8	.0
Average	38.6	35.6	4.4	3.3

Unlike most other cone and seed insects, the spruce budworm does not necessarily complete its larval development within a single cone or seed, but rather may feed on two and occasionally more cones. Frequently, a single budworm will live between two cones growing in close proximity. The insect then may feed on one or both cones. Some cones were fed on from the exterior and were partially destroyed and greatly deformed (fig. 2). Still other cones appeared unharmed except for a small round entrance hole, but upon closer examination they were found to be completely hollow, with only a shell remaining (fig. 3). From the budworm infested cones sampled, an average of about 75 percent of the seed was destroyed.

The budworm larvae usually complete their development by the middle of July. Many of the larvae pupate within the hollowed cone (fig. 4), while others pupate on the foliage.

In a few locations outside the study area, high budworm populations destroyed nearly 100 percent of the cone crop. Within the study area where low budworm populations did not cause significant defoliation, many cones had been attacked suggesting a possible preference for cones (fig. 5).

The role of budworm in Douglas-fir cones will be followed in the future to observe damage under different levels of budworm populations and different sized cone crops.

DOUGLAS-FIR SCALE MIDGE: Contarinia washingtonensis Johnson is very similar to the closely related Douglas-fir cone midge, C. oregonensis, which causes a gall within the cone and either destroys or traps much of the seed. The scale midge causes no gall and only rarely feeds directly on the seed; most of the feeding is restricted to the scales and bracts of the cone. Midges have been found in cones for many years. However, until recently, they haven't been recognized as causing serious injury or reduction of seed yield.

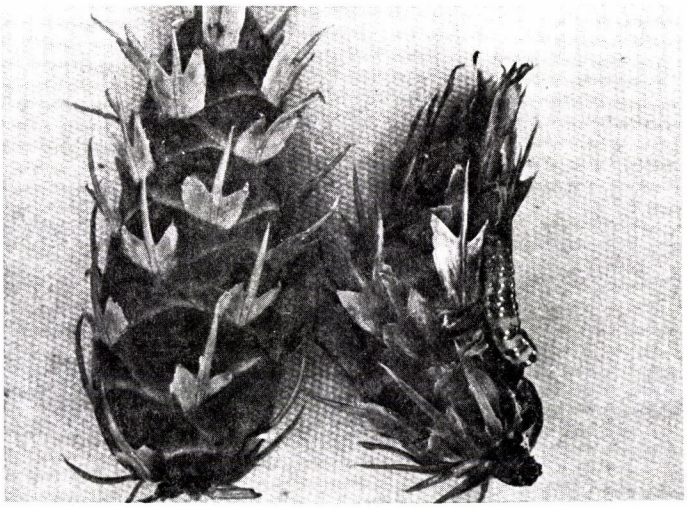

Figure 2.--Normal cone and cone deformed by budworm feeding.

Figure 3.--Budworm hollowing interior of cone.

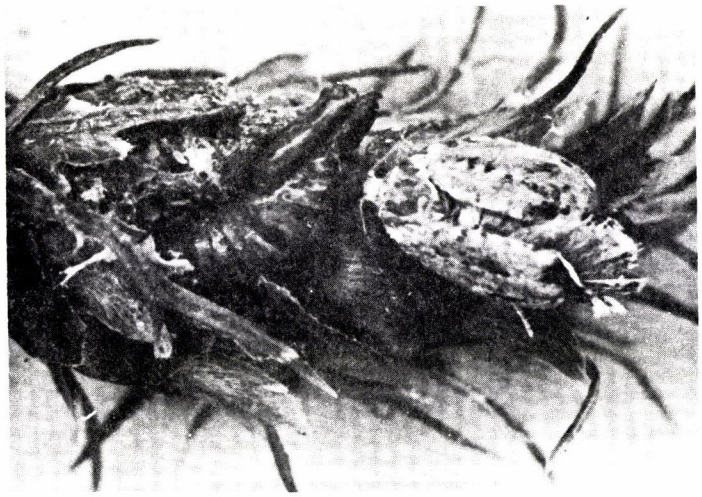

Figure 4.--Budworm pupal case and newly emerged adult.

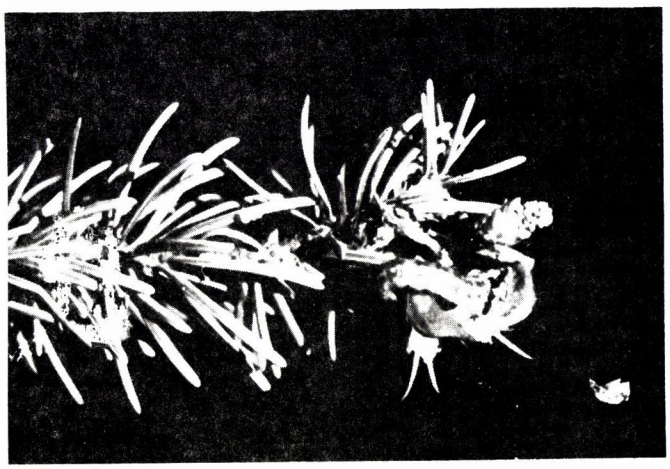

Figure 5.--Budworm and destroyed cone. Note lack of feeding on foliage.

A study conducted by Johnson (1963) showed seed scales heavily infested with C. washingtonensis averaged less than 2 percent filled, whereas uninfested scales were nearly 60 percent filled. Of the uninfested seed, 43 percent germinated, whereas 27 percent of the lightly infested and only 2 percent of the heavily infested seed did so.

Douglas-fir scale midges began showing up in collections about the end of June and increased in numbers until the end of August. By that time, 38.6 percent of the cones sampled were infested with midges. There was a range of 13.8 to 84.0 percent infestation among the plots.

It is difficult to assess the amount of injury inflicted by an insect by measuring such things as reduced viability, but it seems unlikely that a Douglas-fir cone could house an average of 14 midges without suffering considerable ill effects. The injury to the cone occurs during the larval stage (fig. 6). The larvae feed all summer within the cones. They leave the cone in the fall and overwinter in the duff as prepupae. Adult stage begins in late spring or early summer and the cycle is repeated.

MISCELLANEOUS LEPIDOPTERA: This category includes five species:

1. Griselda radicana.
2. Barbara colfaxiana.
3. Dioryctria abietivorella.
4. Chionodes sp.
5. Filatima sp.

Considered individually, their importance was negligible, but when considered as a group they infested an average of 4.4 percent of the cones. Their range of infestation from plot to plot was 0.4 to 23.1 percent.

Of the five insects involved in this group, B. colfaxiana and D. abietivorella are common Douglas-fir cone feeders. These two pests are usually listed in reports on Douglas-fir cone and seed insects.

Chinodes sp. frequently show up on annotated lists of insects from Douglas-fir cones, but G. radicana and Filatima sp. have not previously been reported from Douglas-fir cones. Members of this group were found in cones in early June but did not reach their highest population level until mid-July. Few cones contained more than one larva although some had up to five.

FIR SEED MAGGOT: Earomyia barbara McAlpine has frequently been reported as injuring Douglas-fir cones and seeds, but not as a major pest (fig. 7 and 8). Although it infested an average of 3.3 percent of the cones collected by the end of August, its overall impact apparently was slight. The larva feeds within the cone. It seems to prefer seeds, but is not restricted to them. Ordinarily there is only one larva per cone. Each larva may destroy two or three seeds throughout its development. For E. barbara to be a serious threat to Douglas-fir regeneration, large populations would be necessary. Literature indicates this insect rarely, if ever, builds up in large numbers.

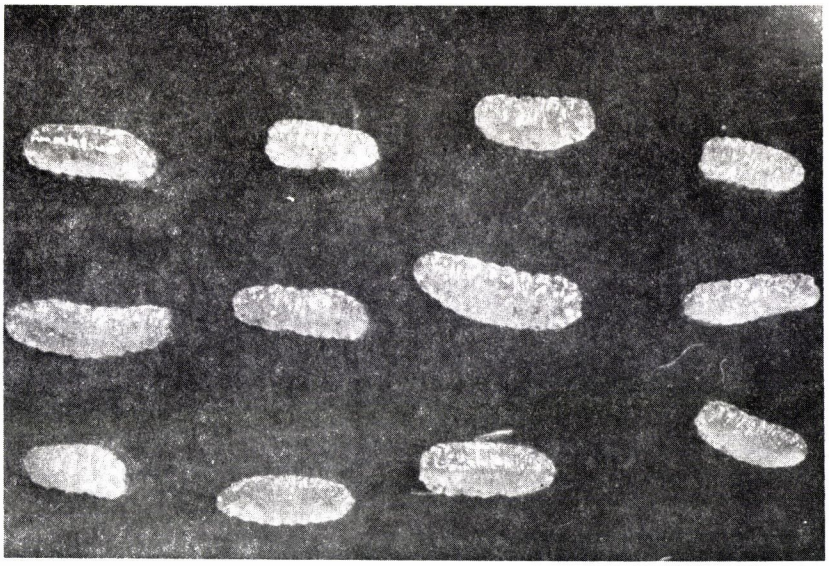

Figure 6.--Contarinia washingtonensis larvae. Actual size is 2.90± 0.33 mm.

Figure 7.--Earomyia barbara larva.

Figure 8.--Earomyia barbara adult.

DOUGLAS-FIR SEED CHALCID: Megastigmus spermotrophus varies tremendously in its seriousness as a seed destroyer from year to year and from area to area (fig. 9). Hussey (1956) reports this insect occasionally infests up to 100 percent of the Douglas-fir seed in areas of Great Britain. In North America, its populations are generally much lower, although it is still frequently considered a major pest. In this study it was found infesting 1.1 percent of the healthy seed. It completes development within a single seed; consequently, seeds need to be examined to determine population density. In late September, after the cones matured, 2,700 seeds, 300 per plot, were collected for dissection. Over 45 percent were hollow. The reason is unknown.

APHIDS AND THRIPS: Every plot sampled had at least 100 aphids, Chermes cooleyi between mid-July and mid-August. Because these insects feed only on the juices and not the tissues, no seeds are destroyed outright. Most were found after the cones were well developed. What damage they cause will probably show up in decreased seed viability. No attempt was made to determine damage levels.

Thrips, Oxythrips sp., and Frankliniella sp., were collected from cones in five of the nine plots. They showed up in early June when the cones were still small. Feeding at this early stage of cone development could cause permanent injury and deformation of the cones. No attempt was made to evaluate thrips injury.

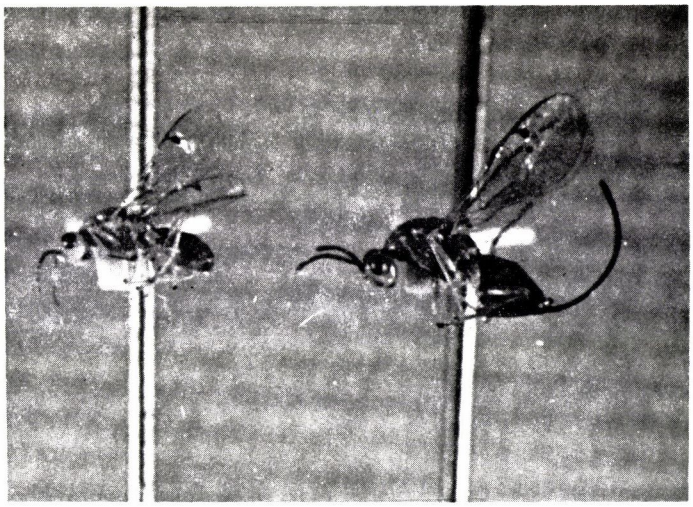

Figure 9.--*Megastigmus spermotrophus* adults.

SUMMARY AND DISCUSSION

About 30,000 Douglas-fir cones were collected from six National Forests in eastern Montana and one area in Yellowstone National Park during the summer of 1967. Cone collections began in late May when the cones were small and continued until the end of September when the seed fell.

Ten species of insects were found feeding on cone or seed tissue, nine species of parasites were present, and two insect species were reared whose role is unknown. The insects involved are listed in order of importance:

1. *Choristoneura fumiferana*
2. *Contarinia washingtonensis*
3. Miscellaneous Lepidoptera
4. *Earomyia barbara*
5. *Megastigmus spermotrophus*
6. *Chermes cooleyi*
7. *Oxthrips* sp. and *Frankliniella* sp.

The spruce budworm, C. fumiferana, has long been recognized as an extremely serious defoliator of numerous conifers but, until this study, has not been reported as causing injury to Douglas-fir cones. As high as 71 percent of the cones had been injured by budworm in one plot. One budworm frequently feeds on one or more cones. Often the foliage adjacent to the cone shows no evidence of budworm feeding, while the cone or cones are almost completely devoured, even though a relatively low budworm population was present.

A significant point is that this study was conducted during a relatively heavy cone crop. The overall budworm population levels are low in the study area; however, over 35 percent of the cones were injured. A higher percentage of the cones might have been destroyed with a light cone crop and high budworm population.

A midge, C. washingtonensis, infested over 38 percent of the sample cones. These cones averaged almost 14 larvae per cone. Although their feeding was less spectacular than budworm feeding, they were blamed for causing reduced seed viability.

Much less damage was attributed to the remainder of the insects encountered.

A total of 2,700 seeds were dissected to check for seed chalcids. Over 45 percent were hollow and infertile. The reason for this is unknown. Only about 1 percent of the healthy seed contained chalcids.

Ordinarily, the larger the cone crop size the smaller the percent of seed destroyed by insects. There was a heavy cone crop in the study area and yet insects destroyed about 50 percent of the seed sampled. More than 45 percent of the remaining seed was hollow. Gashwiler (1967) states that 88 percent of the Douglas-fir seed that reaches the ground is destroyed by birds, small mammals, and other agents before germination is completed. Consequently, even during a good seed year, only a small percent of the seed crop survives the first summer and plays a role in regeneration.

Additional plots will be established in Douglas-fir stands in western Montana during 1968. The study will be expanded to obtain additional information on when budworm make their initial attack on cones.

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